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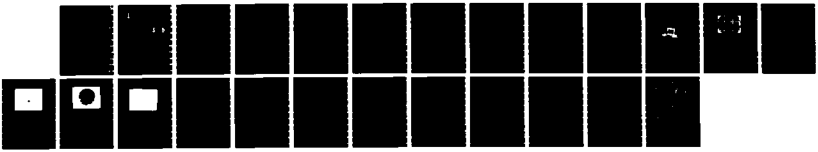

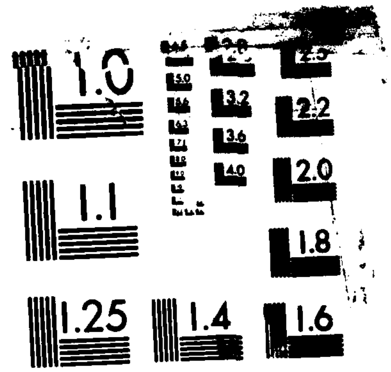

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TECHNICAL REPORT RD-RE-86-1

REAL-TIME PATTERN RECOGNITION USING A MODIFIED LIQUID CRYSTAL TELEVISION IN A COHERENT OPTICAL CORRELATOR

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Research, Development,
and Engineering Center

15 November 1985

U.S. ARMY MISSILE COMMAND
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Liquid Crystal Television (LCTV)
spatial light modulator
real-time pattern recognition

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A commercially available flat screen Liquid Crystal Television (LCTV) has been slightly modified and used as a spatial light modulator in a Vander Lugt type coherent optical correlator. The small, (54 mm x 40.5 mm) inexpensive, (~$100) LCTV was used as a replacement for extremely expensive modulators normally used in optical data processing such as the Hughes Liquid Crystal Light Valve and the Litton Magneto-Optic Device. Results show that the resolution, contrast, and speed of the LCTV in its present form, are sufficient for some basic real-time pattern recognition applications.

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CONTENTS

List of Illustrations

I. INTRODUCTION

The recent availability of inexpensive liquid crystal televisions (LCTV's) has led to experimenting with these devices as coherent spatial light modulators. The basic principle behind the operation of the LCTV is somewhat similar to that of the Hughes Liquid Crystal Light Valve (LCLV) which has been used for some time as an incoherent-to-coherent image converter in real-time pattern recognition systems (References 1 and 2). The 90° twisted nematic liquid crystal structure is common to both the LCTV and the transmission-type LCLV. A major difference in the two devices is the method of addressing. The LCLV is optically addressed (with coherent or incoherent light), while the LCTV must be electrically addressed. Both techniques have their advantages.

One such LCTV (Citizen, model 03TA-0A) has been modified by the removal of the poor quality parallel polarizers attached to both sides of the liquid crystal/electrode grid sandwich. The light diffuser was also removed and the screen hinge modified so that the screen could be positioned vertically as opposed to the designed, approximately 45°, viewing position. Figure 1 is a photograph showing the structural modifications made.

The electrode grid addressing structure (Figure 2) produces an array of 148 horizontal pixels by 122 vertical pixels. The pixel size is approximately 0.22 mm x 0.37 mm. The power consumption of the LCTV is 0.4 watts and can be operated on four AAA batteries for up to 10 hours. An AC adapter was also available for continuous operation. The dimensions of the LCTV, with the liquid crystal screen folded down, are 6.5 mm x 13.5 mm x 2.4 mm, and the weight is about 9 ounces including batteries.

The LCTV was observed to work reasonably well as a normal television set. The resolution was poorer than most standard televisions, but the grey levels and the TV frame rate speed of the device were reasonably acceptable to the eye.

II. EXPERIMENTAL ARRANGEMENT

The basic experimental setup is shown in Figure 3. This is the standard Vander Lugt optical correlator used in many optical data processing experiments - except for the addition of the LCTV (Reference 3). A prefiltering aperture was also included to remove the high spatial frequencies associated with the pixel grid structure of the LCTV. Figure 4 is a photograph of the optical Fourier transform of the unfiltered LCTV screen. The lens used to perform the transform has a focal length of 876 mm. It is obvious from this photograph that any matched filter made with the LCTV will be entirely dominated by the spectrum of the electrode grid structure. In order to minimize this effect, pinholes ranging in diameter from 0.5 mm to 1 mm were incorporated into a prefiltering arrangement. This proved to be quite effective in removing the higher spatial frequencies. Of course this technique may also remove higher frequencies contained in the image displayed on the LCTV. The combination of focal lengths and pinhole size can be chosen to minimize this problem. Initially, the focal lenghts of L_2, L_3, and L_4, shown in Figure 3, were chosen to be 178 mm, 200 mm, and 381 mm, respectively.

The LCTV was addressed using the video input plug provided on the device and a remote video camera. The standard television antenna also allowed the option of RF addressing from an external transmitter. The LCTV may also be used as a monitor for most small computers. This allows computer-generated images to be used to make and/or address the Fourier transform matched filters.

III. EXPERIMENTAL RESULTS

Figure 5 is a photograph showing an example of the coherent images produced by the LCTV in HeNe laser light. The photograph was taken with the 1 mm prefiltering pinhole in the system. Adjusting the brightness control and the automatic gain control of the LCTV produced images in laser light having contrast ratios of 16 - 20 to 1. It was observed that the LCTV was not perfectly effective in rotating the polarization of the incident polarization by 90° (with no power or no image on the device). Regardless of the orientation of the incident polarization and the analyzer, a perfect null in the intensity transmitted by the analyzer could not be found. This may be due to some of the mass construction techniques used in producing the LCTV or perhaps a local distortion of the liquid crystal layer near the electrode grid structure elements. This effect caused the contrast ratio in the coherent image to be considerably lower than images produced by the other light modulators mentioned previously. The observed LCTV contrast ratio was, however, adequate for the experiments performed in this initial study.

The matched filters were made using well-established techniques (Reference 4). The holographic plates (Kodak 649F) were exposed to the filtered Fourier transform of the coherent LCTV image and a reference beam derived from the original collimated laser output. The reference-to-object beam ratio was varied so as to produce the highest diffraction efficiency for the low spatial frequencies contained in the image. The intensity of the reference beam was varied using a pair of crossed polarizers to obtain the desired beam ratio. The exposure times were chosen between 0.25 and 1.5 seconds.

An interesting problem was observed during the course of this investigation. For any pinhole/beam ratio/exposure time combination tested, the correlation signal detected by the CCD television camera shown in Figure 3, was composed of two intensities superimposed. It was found that one of the signals was due to the LCTV screen structure and the other due to the scene being displayed on the LCTV. This was determined by translating the input scene. The signal corresponding to the scene moved on the television monitor which was used to observe the correlation signals. This is a well known property of this type of optical correlator (Reference 5). The signal corresponding to the LCTV structure did not move (see Figure 6). This phenomena has been observed in work with a holographic lens used as the Fourier transform lens (Reference 6). Structure within the hololens produced a background correlation signal very similar to that observed in this report. Figure 7 illustrates the relative intensities of these two signals for a typical correlation. The input scene was a scale model of an M48 tank. The background signal remained reasonably constant regardless of the variations made in the input scene and the correlation signal due to the scene was always highly visible above the background as the input scene was rotated. The quantity of background signal was strongly dependent upon the focal length of the lens and the diameter of the pinhole used in the prefiltering arrangement. Figure 7 also illustrates the normal loss in scene correlation signal as the input scene was rotated. The correlation signals due to the scene and the LCTV were superimposed. The width of the correlation curve was somewhat larger than that obtained using a LCLV in the correlator and a similar input image. This was likely due to the lower resolution of the LCTV. The spatial distribution of the correlation signal is given in Figure 8. This data was taken using the TV line sweep capability of the Colorado Video image digitizer.

IV. CONCLUSIONS

In this initial investigation, it has been shown that small, inexpensive, liquid crystal televisions may be used as spatial light modulators in some real-time optical correlation applications. The LCTV used in this research was modified by the removal of the original polarizers used on the device. These polarizers were replaced with external, high quality polarizers, and it was found that the contrast of the resulting coherent (HeNe laser) image was greatly improved. This improvement in contrast was enough to investigate the possibility of using the LCTV as a real-time spatial light modulator. Inital results presented in the report show that the LCTV performs reasonably well in a standard coherent optical correlator and that the device deserves a much closer examination so that its operating parameters, such as resolution, contrast, and speed may be optimized for general optical data processing needs.

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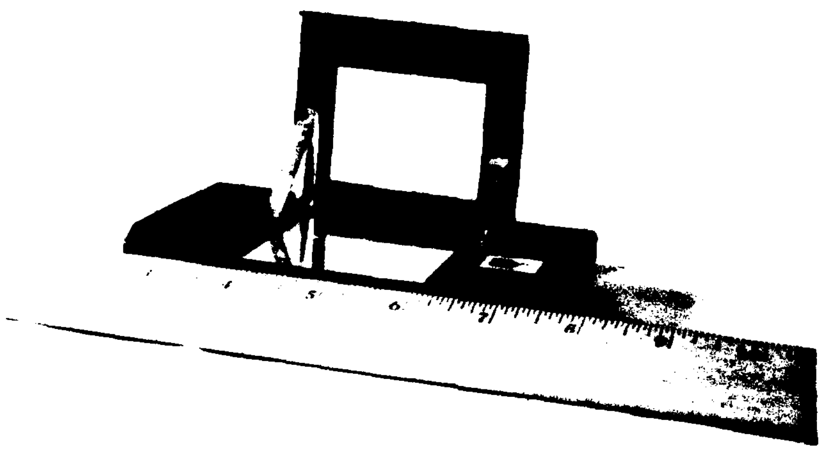
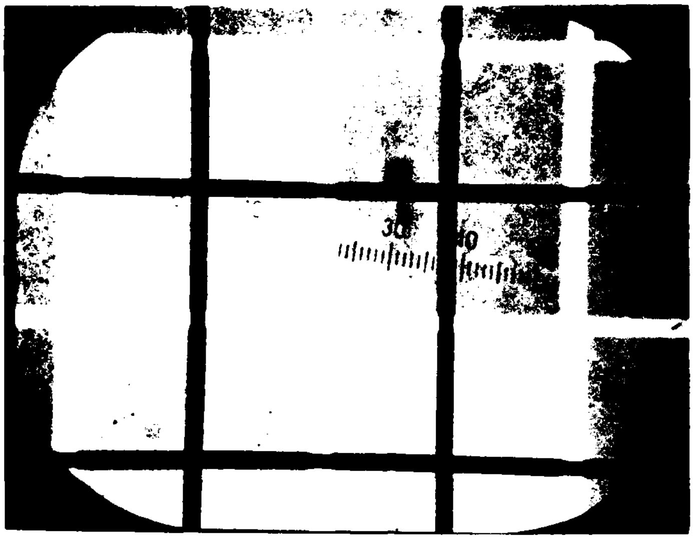


Figure 1. Modified liquid crystal television.



NOTE: This photograph was made before the external polarizers were removed and while an image was being displayed on the screen.

Figure 2. Pixel structure of the liquid crystal television.

L_1 - L_5 = Lenses
S = Jodon spatial filter
SH = electronic shutter
M_1, M_2, M_3 = mirrors
BS = Coated beam-splitter
P_1 - P_4 = polarizers
PH = pinhole
F = holographic film plate

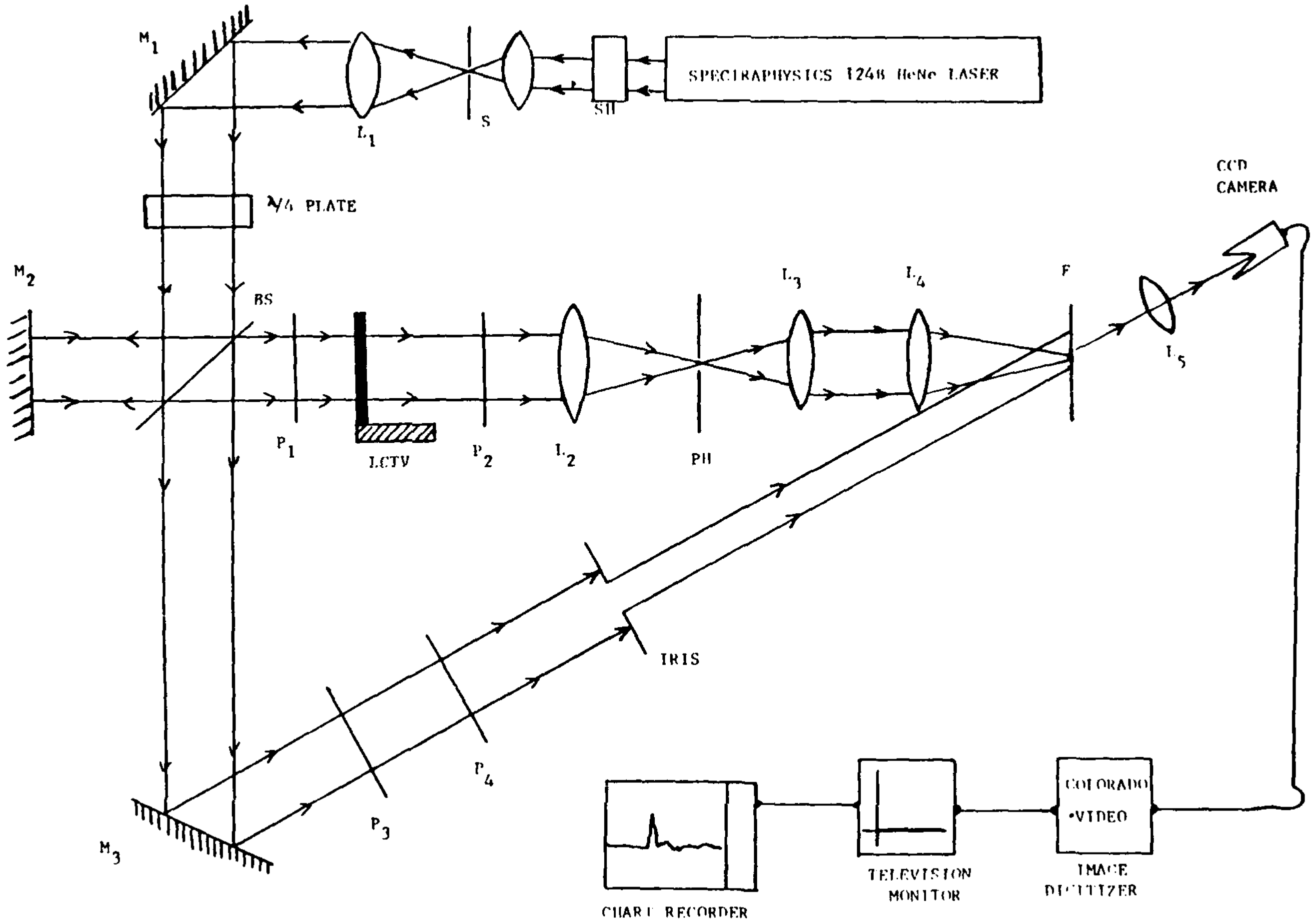
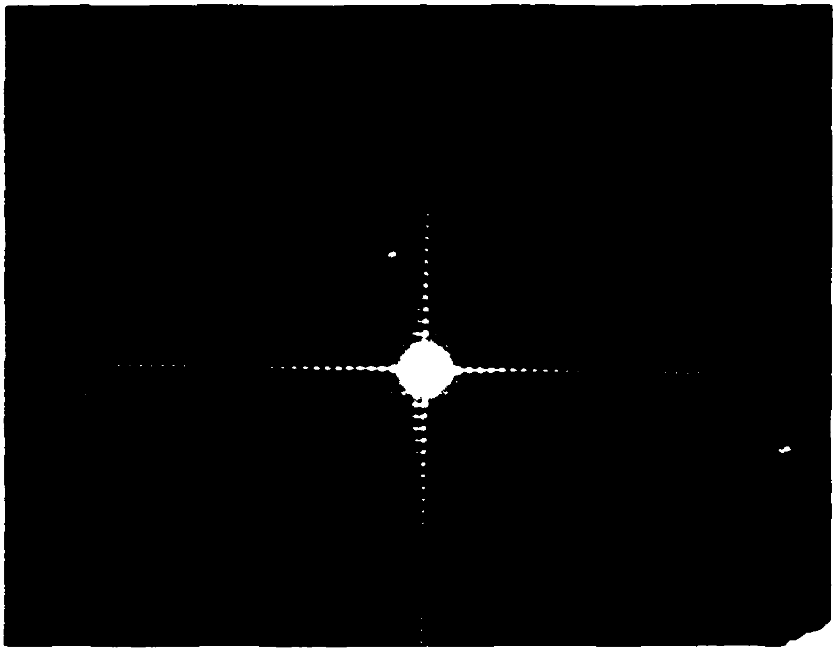
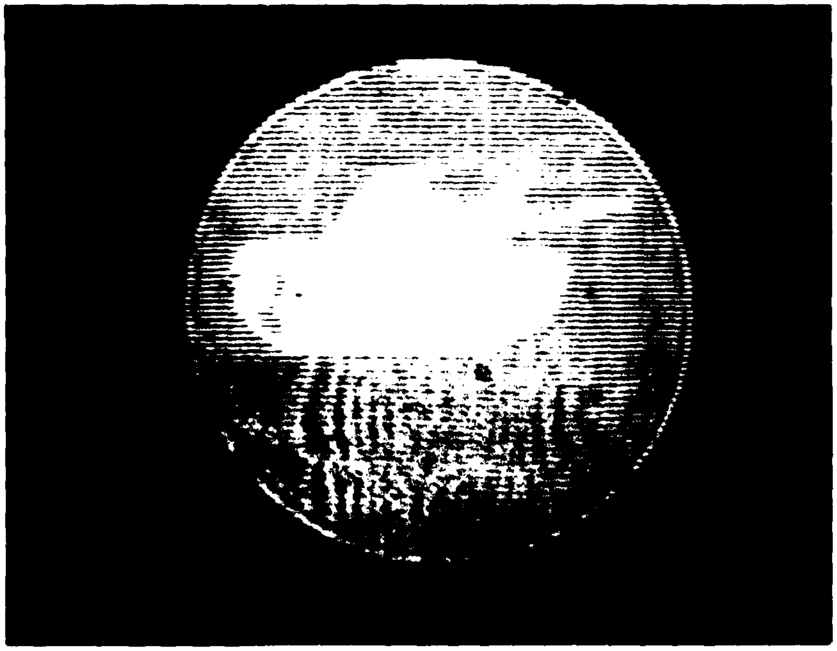


Figure 3. Experimental arrangement showing the location of the liquid crystal television (LCTV) and the prefiltering scheme.



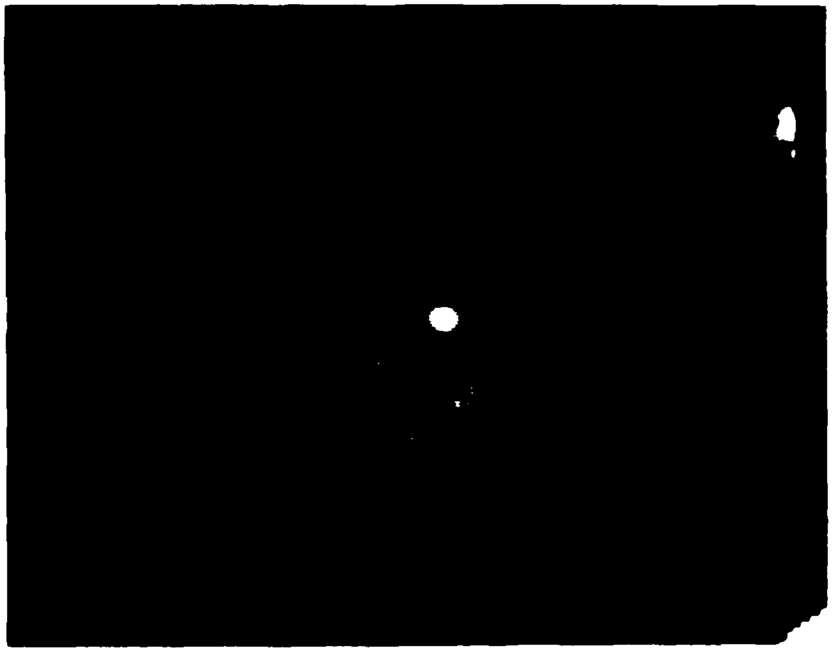
NOTE: The transform lens used for this photograph had a focal length of 876 mm.

Figure 4. Optical Fourier transform of the pixel structure of the liquid crystal television.



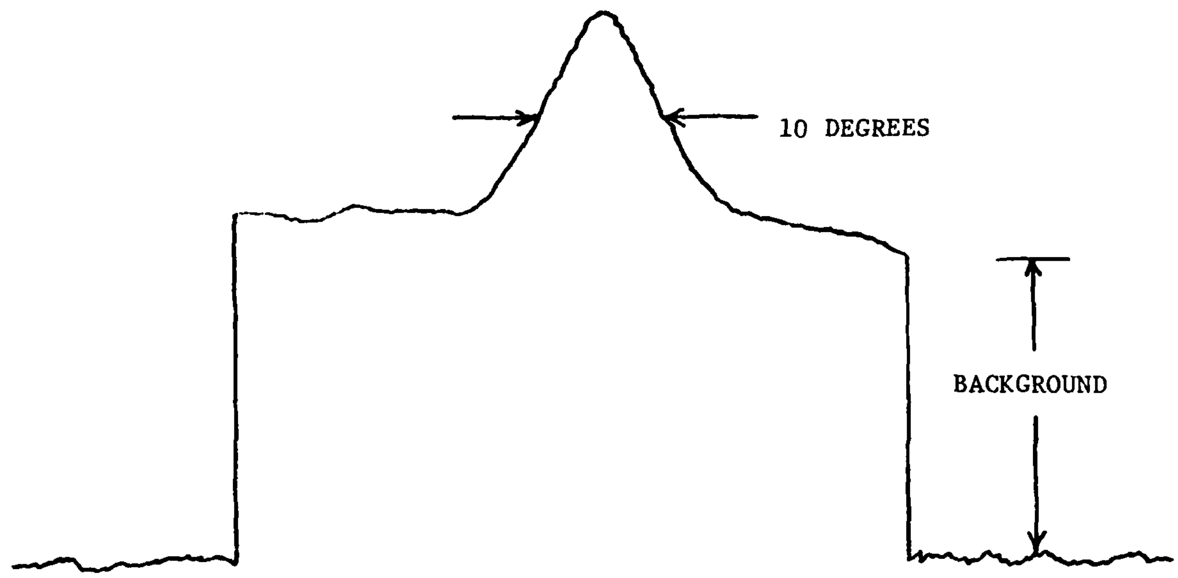
NOTE: The image has been prefiltered by the arrangement shown in Figure 3 using a 1 mm diameter pinhole.

Figure 5. Tank model displayed on the liquid crystal television in Helium Neon laser light.



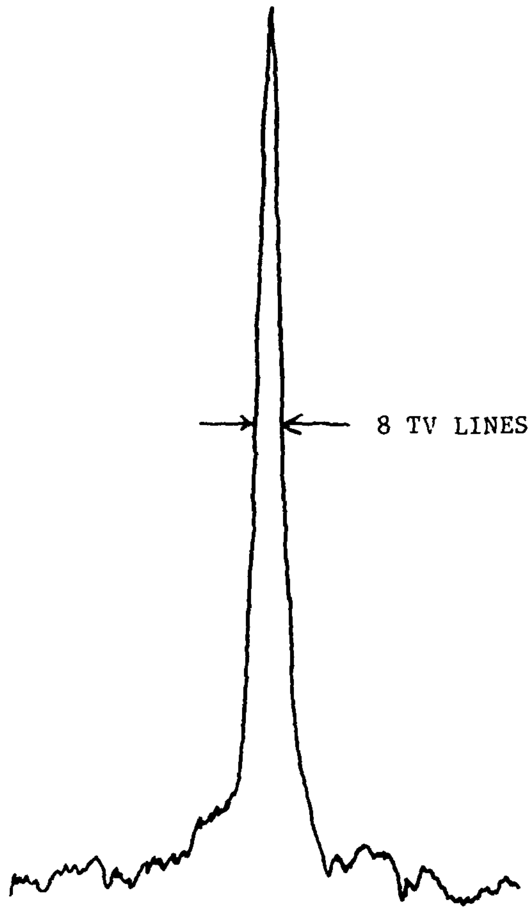
NOTE: The two signals were separated by translating the tank model. A 0.5 mm diameter pinhole was used as a prefilter.

Figure 6. Television monitor displaying the correlation signals due to the structure of the liquid crystal television, (upper bright spot), and the tank image, (lower bright spot).



NOTE: This data shows the background intensity due to the structure of the liquid crystal television. This background can be decreased somewhat by using a smaller pinhole in the prefiltering arrangement shown in Figure 3. A 1 mm diameter pinhole was used in obtaining the data above.

Figure 7. Correlation intensity versus rotation of the input scene.



NOTE: The scene and background signals have been separated as in Figure 6. The above data is for the scene correlation only. The input scene used was a scale model of an M48 tank.

Figure 8. Spatial distribution of the correlation signal as displayed on a standard television monitor.

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